THE SKY

Questions

How do we orient objects in the sky?

How do we find objects on the moving sky?

What about the moving objects?

How is the Earth (and how are humans) affected by the sky?

Observations and Theories

The Ancient Greeks and Egyptians developed theories to explain their observations. However, they maintained several postulates (e.g., circular motion), which prevented a truly impartial theory.

A. Geocentric Cosmology

1. Earth appears to be flat.
2. Celestial Sphere appears to be above the Earth.
3. Celestial Sphere moves around the Earth.

    Most stars are fixed.

    Stars rise in East, set in the West.

Observations and Theories

B. Wandering Stars

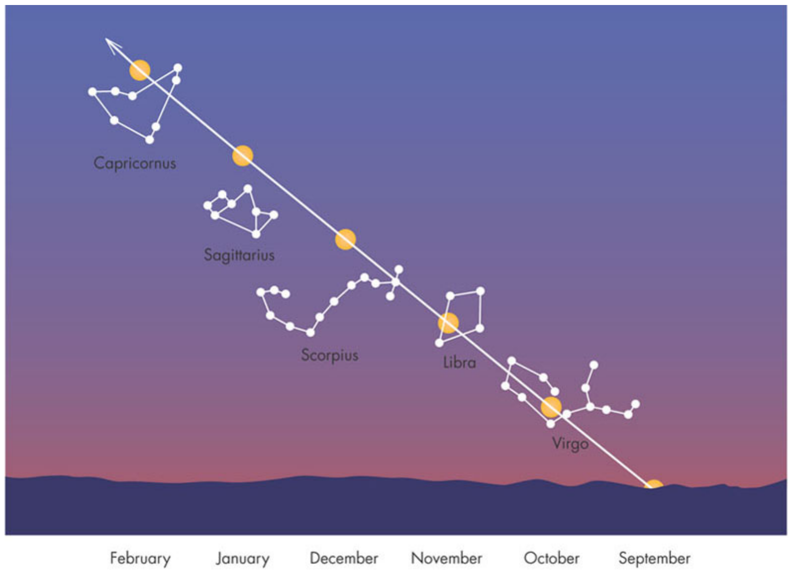
Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn

C. The Sun's Motion

Sun travels on the ecliptic. There is a 4 minute difference per day of the Sun's position against the stars. The angle between the Earth's orbit and the Earth's rotation axis is 23^{o} (obliquity).

D. Zodiac along the Ecliptic

Constellations are groups of stars. Today, there 88.



Questions

How far away is Mars?

How big is the Andromeda Galaxy?

Distances

Many people find the Heavens to be incomprehensible because of the great range in sizes and distances. Even astronomers have a difficult time coming to grips with quantities like the distance from the Earth to the Sun when it is expressed as 93,000,000 miles (150,000,000 km). The way to comprehend sizes and distances is to use meaningful measurement units.

Distances

Here is an example. The distance from my house in Atlanta to my parents' house north of Nashville is about **17,740,000 inches** – the number is correct but it is completely meaningless because we do not have a real-world feel for numbers that large.

I could state that the distance is about **280 miles**. The number 280 is just on the verge of our ability to comprehend its magnitude.

An even better way of relating the distance between the houses is to say it takes me **4 hours** to drive from one to the other. In expressing it that way, two things have happened: (1) the quantity of 4 hours is easily comprehensible and (2) the measurement units were switched from distance to time. Hopefully by this change in measurement units, you get a better feel for the distance between these two homes.

What is a Good Distance Unit?

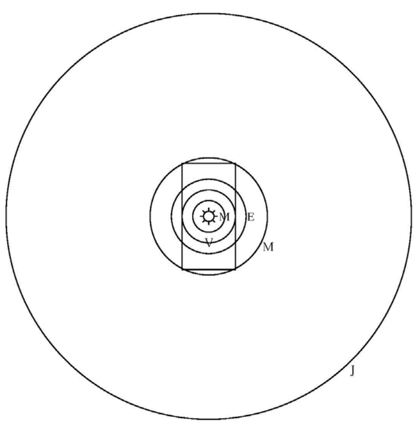
Astronomers recognized the need for better distance measurement units in the Solar System, Galaxy, and the Universe, since the mile is just too short to be useful. The unit for the **Solar System** is based on the average distance from the Earth to the Sun.

Instead of using 93 million miles (150 million km), this distance is defined as equal to 1 and is called the **Astronomical Unit** (AU).

$$1 \text{ AU} = 1.5 \times 10^8 \text{ km}$$

With this relative scale, we would say that the distance from the Sun to Mercury is 0.4 AU, to Mars it is 1.6 AU, to Jupiter it is 5.2 AU, and to Pluto it is on average about 40 AU.

Scale of the Solar System

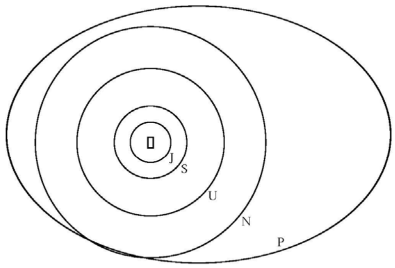


Shrink the Sun down to the size of a basketball.

Put it on the 50 yard line of the GT football field.

Note the spacing of the inner planets – all would fit on the football field.

Scale (cont.)



Note the spacing of the outer planets – much larger than the football field.

PLANET	DISTANCE		DIAMETER		MASS
	(AU)	(yd)	(E=1)	(mm)	(E=1)
Mercury	0.39	10	0.38	1	0.06
Venus	0.72	18	0.95	2	0.81
Earth	1.00	25	1.00	2	1.00
Mars	1.52	37	0.53	1	0.11
Jupiter	5.20	128	11.20	22	317.8
Saturn	9.54	235	9.41	18	94.3
Uranus	19.18	472	4.11	8	14.6
Neptune	30.06	740	3.81	7	17.2
Pluto	39.44	971	0.17	0	0.01

Question

How far to the nearest star?

If the Sun is the size of a basketball,

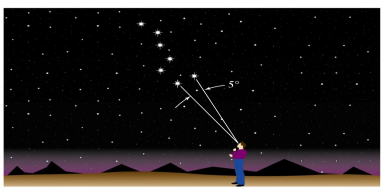
the next nearest basketball would be in

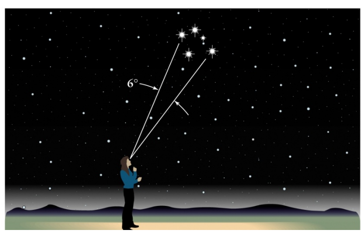
____

What About Angles on the Sky?

Angular Diameters

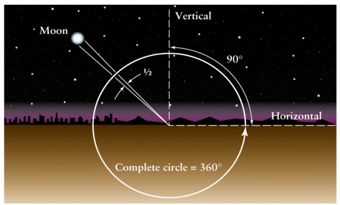
Full Moon = Sun
= 0.5^{o}
= 30 arcmin
= 1,800 arcsec

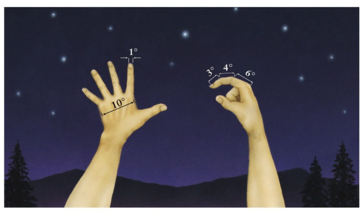




Universe by Freedman, Geller, and Kaufmann

Measuring Angles





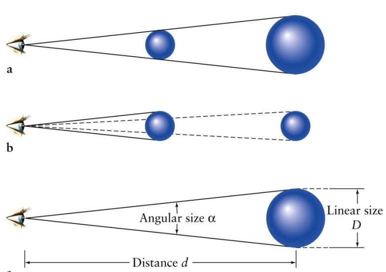
Universe by Freedman, Geller, and Kaufmann

Circle

360° in Circumference

$$\frac{\alpha}{360^{o}} = \frac{x}{2\,\pi\,R}$$

Angular Measurements



Universe by Freedman, Geller, and Kaufmann

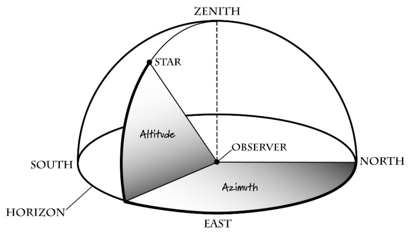
Skinny Triangle

$\tan \alpha = D / d$

[Diameter / distance]

$\alpha = D / d$ (radians)

Local Coordinates



Relative to the Observer

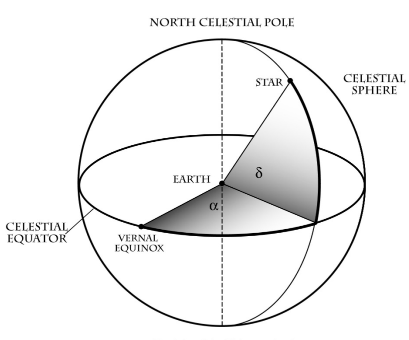
Zenith is a point directly over-head.
Meridian is a line through the Poles and Zenith.

Star Positions

Azimuth is angle from North

Altitude is angle from Horizon

Celestial Coordinates



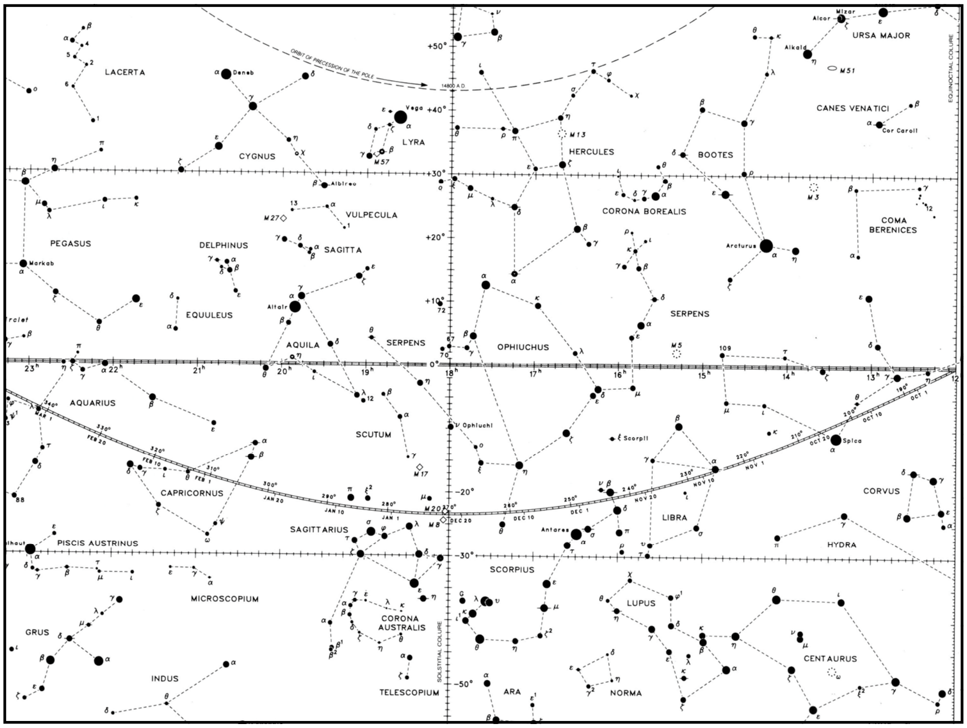
Celestial Poles are above the North & South Poles.

Celestial Equator is directly above the Earth's Equator.

Star Positions

Longitude = Right Ascension (α)

Latitude = Declination (δ)



H8 BRIGHT STARS, J1998.5

Flamsteed/Bayer Designation			HR No.	Right Ascension	Declination	Notes	V	$U-B$	$B-V$	Spectral Type
				h m s	° ′ ″					
11	v1032	Ori	1638	5 04 29.0	+15 24 08	fv	4.68	−0.09	−0.06	A0p Si
	η^2	Pic	1663	5 04 55.7	−49 34 47	fv	5.03	+1.88	+1.49	K5 III
2	ϵ	Lep	1654	5 05 23.9	−22 22 23	fv	3.19	+1.78	+1.46	K4 III
	ζ	Dor	1674	5 05 29.1	−57 28 29	f	4.72	−0.04	+0.52	F7 V
10	η	Aur	1641	5 06 24.6	+41 13 57	fv	3.17	−0.67	−0.18	B3 V
67	β	Eri	1666	5 07 46.5	− 5 05 18	fvd	2.79	+0.10	+0.13	A3 IVn
69	λ	Eri	1679	5 09 04.5	− 8 45 21	fv	4.27	−0.90	−0.19	B2 IVn
16		Ori	1672	5 09 14.7	+ 9 49 40	fvmd6	5.43		+0.24	A9m
3	ι	Lep	1696	5 12 13.7	−11 52 15	d	4.45	−0.40	−0.10	B9 V:
5	μ	Lep	1702	5 12 51.8	−16 12 26	fsv	3.31	−0.39	−0.11	B9p Hg Mn
4	κ	Lep	1705	5 13 09.7	−12 56 36	d7	4.36	−0.37	−0.10	B7 V
17	ρ	Ori	1698	5 13 12.7	+ 2 51 34	vd67	4.46	+1.16	+1.19	K1 III CN 0.5
11	μ	Aur	1689	5 13 19.5	+38 28 58	f	4.86	+0.09	+0.18	A7m
	θ	Dor	1744	5 13 45.5	−67 11 13	f	4.83	+1.39	+1.28	K2.5 IIIa
19	β	Ori	1713	5 14 27.9	− 8 12 12	fsvd6	0.12	−0.66	−0.03	B8 Ia
13	α	Aur	1708	5 16 34.7	+45 59 48	fcvd67	0.08	+0.44	+0.80	G6 III + G2 III
	o	Col	1743	5 17 25.8	−34 53 48	f	4.83	+0.80	+1.00	K0/1 III/IV
20	τ	Ori	1735	5 17 32.0	− 6 50 45	fsd6	3.60	−0.47	−0.11	B5 III
15	λ	Aur	1729	5 19 02.1	+40 05 52	fd	4.71	+0.12	+0.63	G1.5 IV–V Fe–1
	ζ	Pic	1767	5 19 19.9	−50 36 27	f	5.45	+0.01	+0.51	F7 III–IV

Motions in the Sky

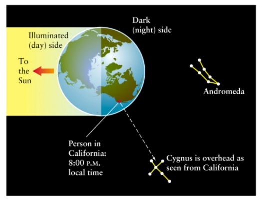
Motions

Two Motions

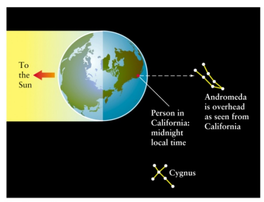
Rotation – The spinning of a body around its axis (one day).

Revolution – The orbital motion of a body around another due to Gravity (one year).

Diurnal Motion



a Earth as seen from above the North Pole



b 4 hours later

Universe by Freedman, Geller, and Kaufmann

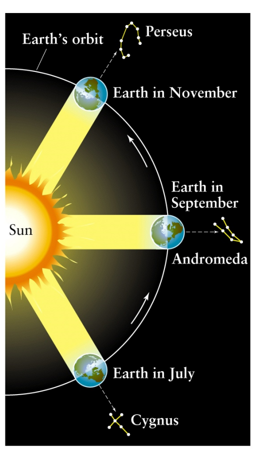
Effects Due to Rotation

Gives us Night and Day.

Causes the Sun and Stars to rise in the East and set in the West.

If there was no Revolution, then each night sky would be the same.

Seasonal Changes

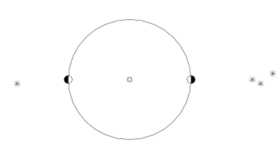


Universe by Freedman, Geller, and Kaufmann

Effects Due to Revolution

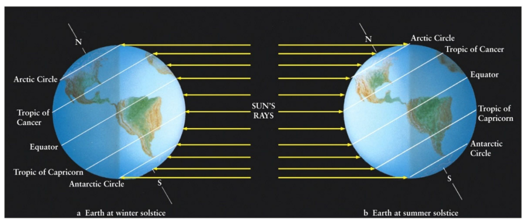
Gives us the Year.

Has a role in producing the Seasons, which are not due to a change in distance.



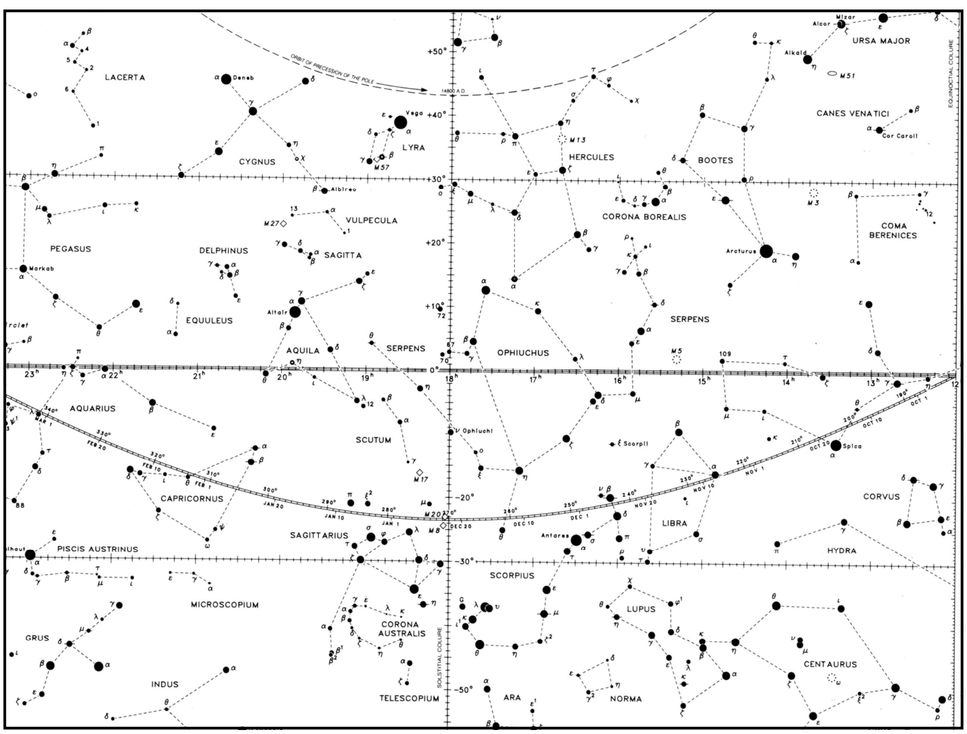
Path of the Sun

Sun's Path is the Ecliptic.

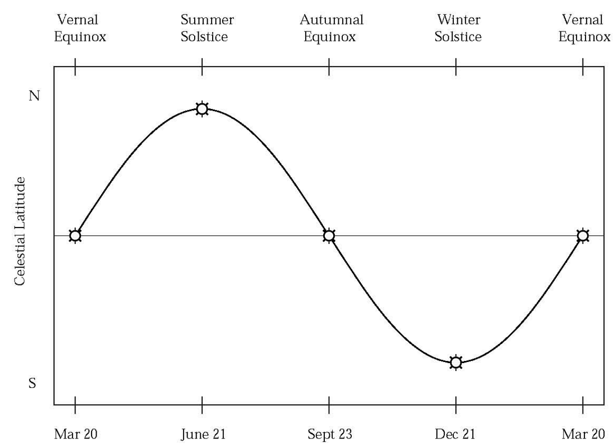


The Earth's tilt (obliquity) of 23.5^o is what causes the Sun's path not to be on the Celestial Equator.

Universe by Freedman, Geller, and Kaufmann



Yearly Solar Motion



The Year

Julian Calendar

46 BC

1 year = 365.2500 days

1 leap day is added if the year is evenly divisible by 4.

Think about it – Should the year and day be nicely linked?

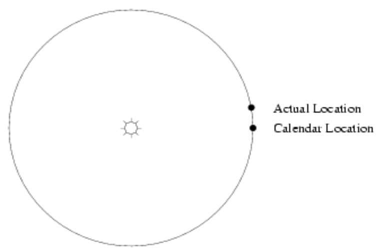
Problem is that

1 year = 365.2422 days

(a difference of $11^{m}\ 14^{s}$)

Think about it – Should this difference cause a problem?

The Year (cont)



Gregorian Calendar

AD 1582

Easter's Date had shifted

Two Adjustments

Removed 10 days

Oct 4 ➔ Oct 15, 1582

The Leap Year

If the year is evenly divisible by 4,
Yes, unless

If the year is evenly divisible by 100,
No, unless

If the year is evenly divisible by 400,
Yes

The Day

Universe by Freedman, Geller, and Kaufmann

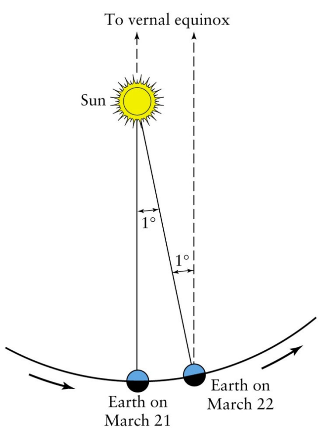
Solar Day

If there was only the Rotation of the Earth, then the day would be

$= 24^h\ 00^m\ 00^s$

Think about it – this would be the time from one crossing of the Meridian to the next crossing by the Sun. (am & pm)

The Day (cont.)



Universe by Freedman, Geller, and Kaufmann

Sidereal Day

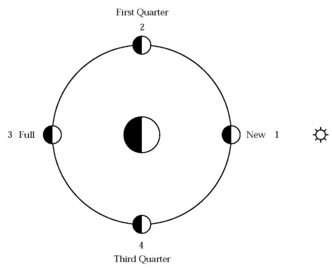
But the Earth is also Revolving while it is Rotating, so with respect to the background stars, one day

$= 23^h\ 56^m\ 04^s$

Think about it – there are 360º in a circle and there are 365.25 days in a year.

Phases of the Moon

View from High Above
the Earth's North Pole

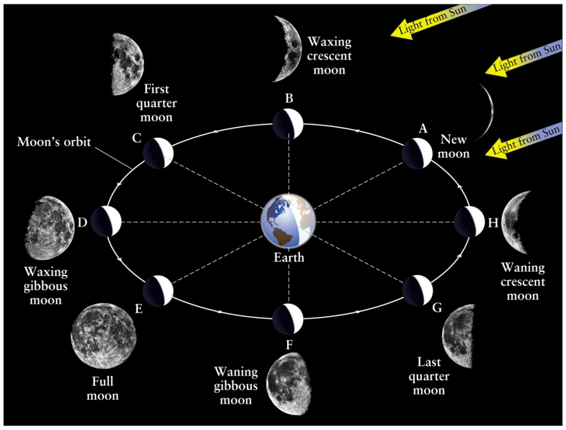


Phase depends only on the orientation of the Moon to the Earth and Sun.

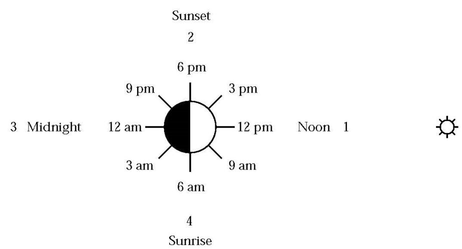
It does not matter what time of day it is.

For example, the Moon is Full at position 3 whether it is noon or midnight on the Earth.

All Lunar Phases



Times of Day

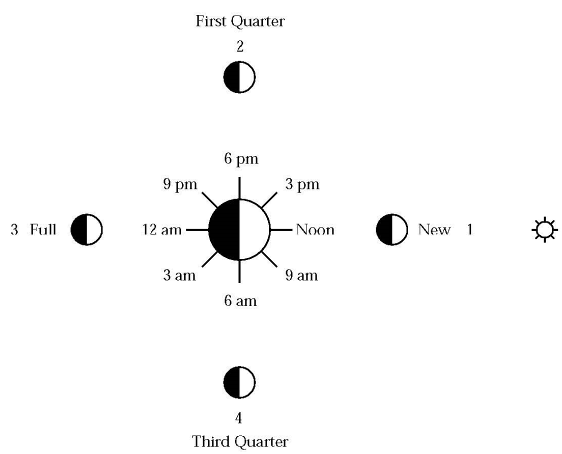


The time of day depends solely on the altitude of the Sun.

The Moon plays no role in establishing the time.

For example, it can be midnight, and the phase of the Moon can be anything.

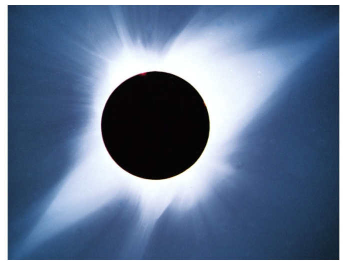
Phases & Times



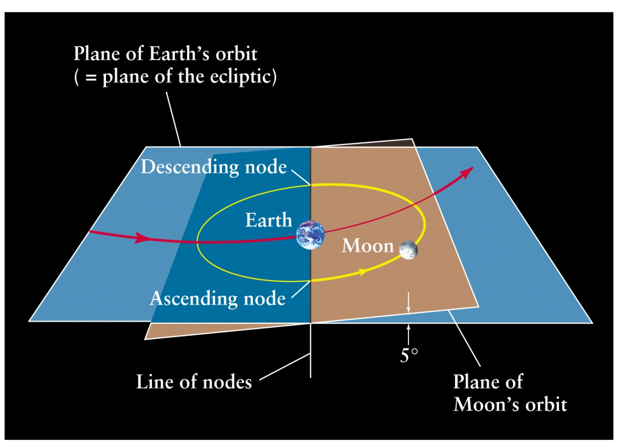
Eclipses

Lunar

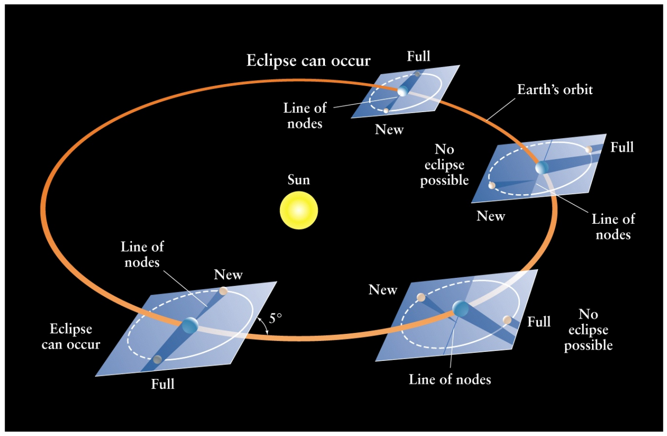
Solar



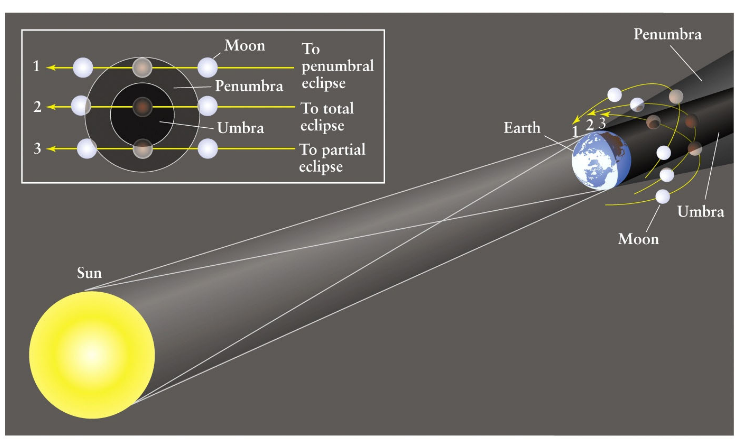
Inclination of Moon’s Orbit



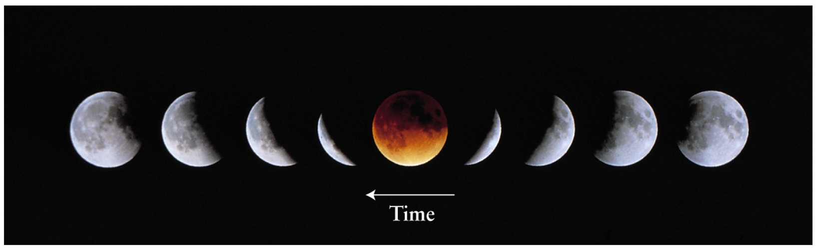
Conditions for Eclipses



Geometry of Lunar Eclipses



A Total Lunar Eclipse

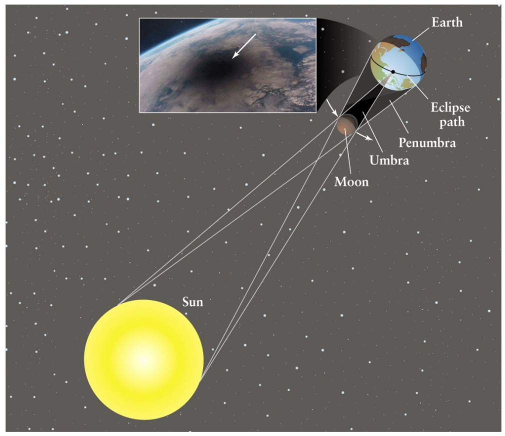


January 20-21, 2019 (Sunday)

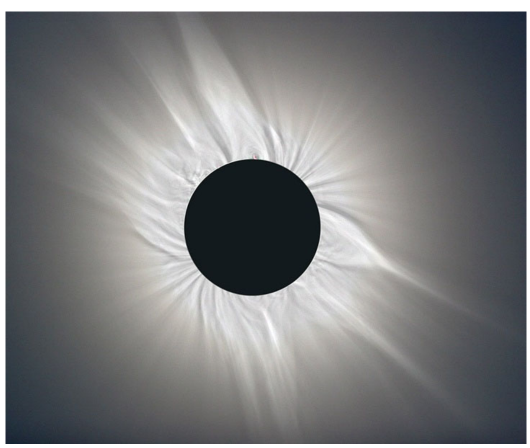
Event	**Time**
Penumbral Eclipse begins	Jan 20 at 9:36 PM
Partial Eclipse begins (*)	Jan 20 at 10:34 PM
Full Eclipse begins (*)	Jan 20 at 11:41 PM
Maximum Eclipse	Jan 21 at 12:12 AM
Full Eclipse ends	Jan 21 at 12:43 AM
Partial Eclipse ends	Jan 21 at 1:50 AM
Penumbral Eclipse ends	Jan 21 at 2:48 AM

† The Moon is above the horizon during this eclipse, so with good weather conditions in Atlanta, the entire eclipse is visible.

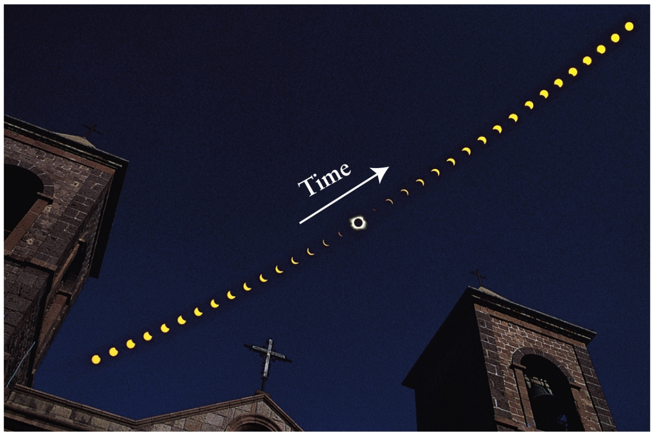
Geometry of Solar Eclipses



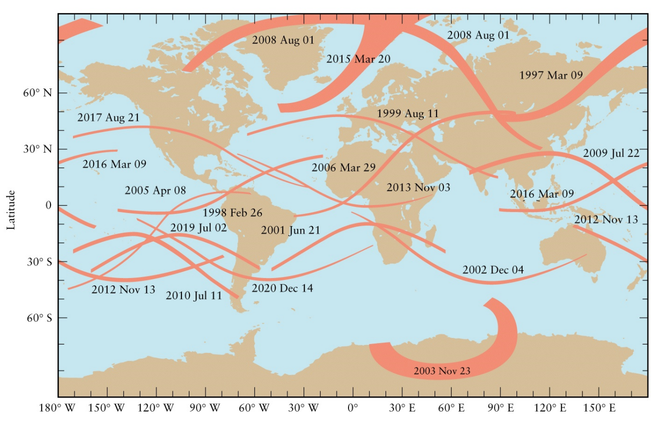
A Total Solar Eclipse



A Total Solar Eclipse



Eclipse Paths



Key Individuals

Pythagoras [d. 497 BC, Italy]

Aristotle [384 - 322 BC]

Aristarchus of Samos [310 - 230 BC]

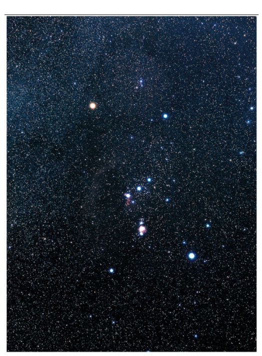
Eratosthenes [276 - 195 BC, Alexandria, Egypt]

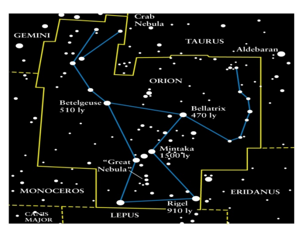
Hipparchus [160 - 127 BC, Alexandria, Egypt]

Claudius Ptolemy (or Ptolemaeus) [AD 140]

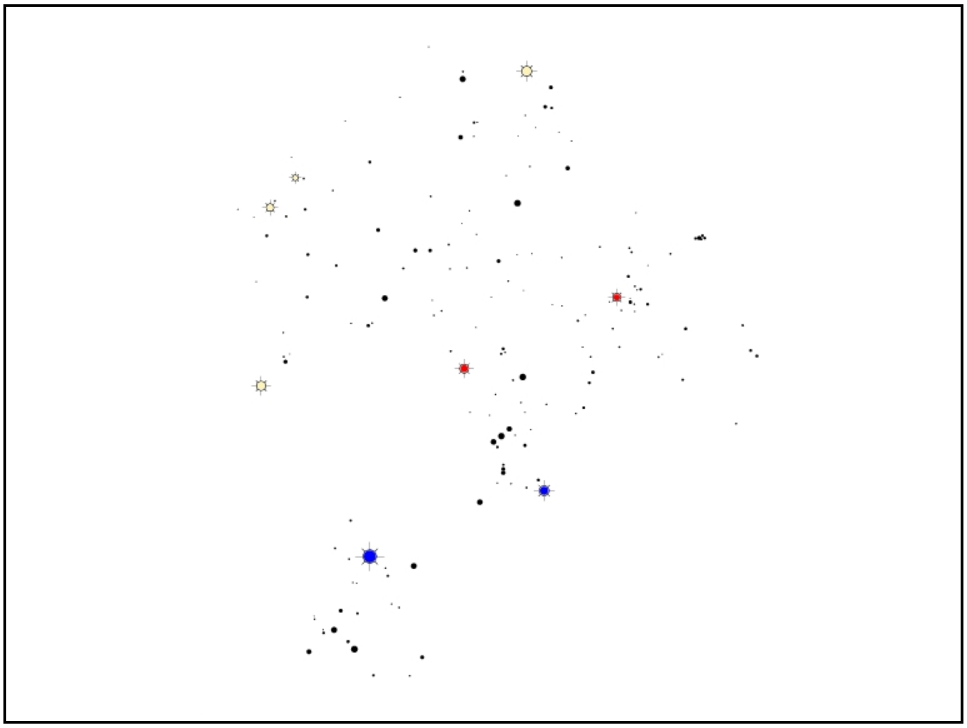
Hipparchus [160 - 127 BC]

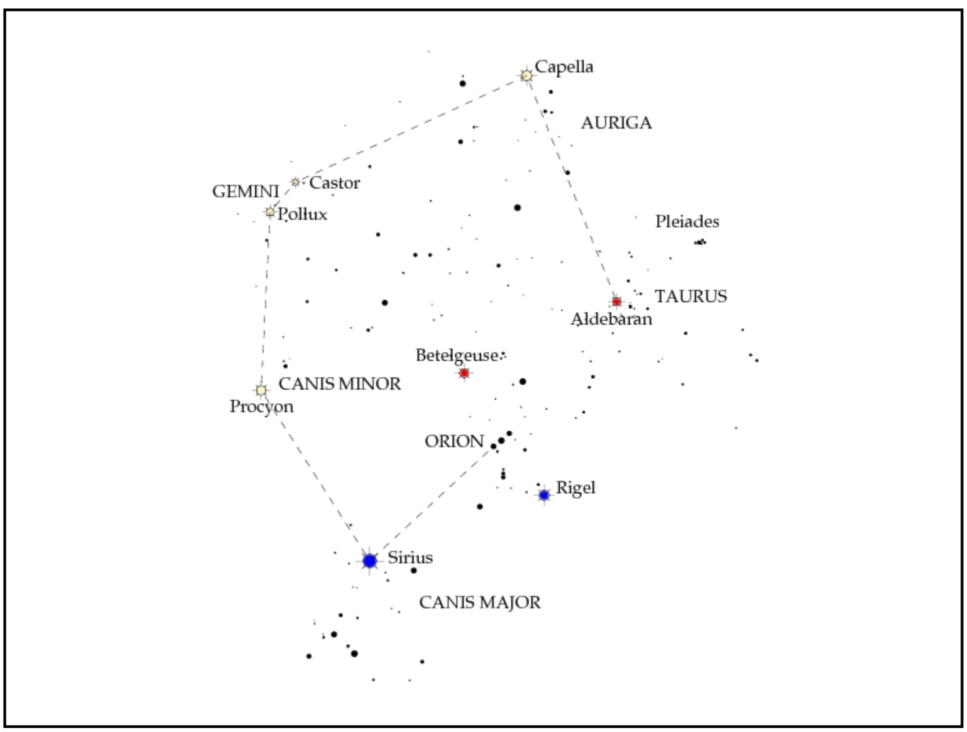
He cataloged 850 stars by position and by magnitude.





Universe by Freedman, Geller, and Kaufmann




Capella
AURIGA
Castor
GEMINI
Pollux
Pleiades
TAURUS
Aldebaran
Betelgeuse
CANIS MINOR
Procyon
ORION
Rigel
Sirius
CANIS MAJOR